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ScienceDirect
Journal of Forensic and Legal Medicine 14 (2007) 190–194
JOURNAL OF FORENSIC AND LEGAL MEDICINE
www.elsevier.com/jflm

Original communication

Determination of sex from the femur in Anatolian Caucasians: A digital radiological study

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Received 8 February 2006; received in revised form 27 March 2006; accepted 14 May 2006
Available online 18 January 2007

Abstract

Determination of the sex is one of the most important steps when evaluating decomposed bodies or skeletal remnants. However, relevant data exhibit significant ethnic and temporal variation. This study provides information on in vivo femoral dimensions of Anatolian Caucasians. 50 males and 54 females with ages between 18 and 68 years were investigated with computed tomography. For males, mean maximum length (ML) was 448.2 mm, mean vertical head diameter (VHD) was 48.8 mm, mean midshaft transverse diameter (MTD) was 26.5 mm, and mean anterior bowing (AB) was 759.3 mm. For females, these were 419.0 mm, 43.4 mm, 25.6 mm, and 779.5 mm, respectively. Femoral dimensions of Anatolian Caucasians were not entirely similar to a single racial group that was already reported. There was a significant difference between males and females regarding ML and VHD ($p < 0.0001$ for both). MTD and AB did not exhibit sexual dysmorphism. Discriminant analysis for sex type produced 83.3% accuracy when ML was used, and 76.9% accuracy when VHD was used ($p < 0.0001$). Combined use of both parameters increased overall accuracy to 84.6% ($p < 0.0001$). For VHD, cut-off value of 44.9 mm produced 94% sensitivity and 83% specificity. For ML, cut-off value of 428.6 produced 80% sensitivity and 67% specificity.

Keywords: Sex determination; Femur; Anatolian Caucasian; Computed tomography

1. Introduction

Criminals may destroy the remains of their victims to make their identification difficult. Therefore, establishing identity from the skeletal remains is of vital importance in the field of forensic osteology and sex determination is one of its most important steps. Various anthropometrical measurements are being used for that purpose. However, data that are obtained for one ethnic group is not usually applicable to others.[1,2] This data also differ temporally within the same ethnic group.[3,4]

Various studies dealing with sex determination from femoral measurements can be found in the relevant literature. Samples of white South Africans,[5] white North Americans,[6] Germans,[7] Portuguese,[8] Chinese[3,4] and ethnic North Americans[9] were already reported. Above-mentioned samples belong to late 19th and 20th century. Sexual dimorphism was also studied in a prehistoric population.[10] Maximum length, maximum midshaft diameter, condylar width, and vertical and transverse head diameter were among the commonest measurements.[1–10] Some researchers used additional parameters such as head circumference to improve overall differential accuracy.[1]

Above-mentioned measurements were performed on dissection samples after removing soft tissues, muscles, tendons and ligaments, or on bone collections. Digital radiography is an alternative and accurate measurement technique that can be used on living subjects.[11] It does not depend on to the availability of cadaver samples, and may give the opportunity to analyze greater number of subjects in a shorter period. However, it is an expensive technique and was not readily available until recently. Therefore, digital radiography was not used for forensic femoral measurements.

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1353-1131/$ - see front matter
doi:10.1016/j.jcfm.2006.05.008

In this study, the sexual differences of femoral dimensions were investigated in living Anatolian Caucasians. In addition to three conventional parameters (maximum length – ML, vertical head diameter – VHD, midshaft transverse diameter – MTD), an additional parameter (anterior bowing – AB) was also measured. Digital radiographic images were used to obtain in vivo measurements.

2. Materials and methods

2.1. Study subjects

The study subjects were Caucasian adults living in Eastern Anatolia. They were presented to our institution for irrelevant minor causes such as otorhinolaryngological or dermatological problems or were recruited from the companions of patients who were presented to the same institution. The institutional review board for clinical investigation at this facility approved the investigational protocol, and informed consent was obtained from all subjects.

Candidates were excluded if they had been given a diagnosis of chronic illness or if they were inactive for their respective ages. They also underwent a general physical examination performed by an orthophaedist for any orthophaedic disorder and they were excluded from the study if such a disorder was found. The final group was consisted of 104 subjects. There were 50 males and 54 females, with ages between 18 and 68 yrs (mean: 40.9, SD: 14.7). These subjects were also used for another clinical study on femoral nails.[11]

2.2. Femoral measurements

Frontal and lateral digital radiographic views (computed tomography scanograms) of both lower extremities were obtained using computed tomography (CT) scanner (Secura, Philips, Best, the Netherlands). In the scanogram mode, current multislice CT scanners have the capability to obtain a continuous digital image up to 180 cm or more. Their field of view is much larger than the one that is reached by the flat panel detectors of the current digital radiography equipments, which is usually up to 40 cm. Greater field of view is necessary to image long structures such as femora or the entire body. CT also has the advantage of sectional imaging in the same session and of archiving the raw images in DICOM format for future studies.

During each scanning, subjects were placed in a supine position. Anteroposterior and lateral scanograms were obtained using the setting below: kVp 140, mA: 100, Rotation time: 1.0 s, Slice thickness: 1.0 mm.

For frontal views both legs were kept in extension. For lateral views, a sponge pillow was put beneath right the hip in order to keep it flexed between 40° and 45°. This method had prevented proximal radiological overlapping of the right and left femurs. For lateral views, the detector array was situated in the left side of the scanner. The left femur was closer to the detector array of the scanner and was relatively free of magnifying effects. Therefore, left femurs were used for all measurements. Radiographic views were hard copied on video films on which measurements were performed.

ML, VHD and MTD were measured on frontal views according to the method of Martin and Saller[12] (Fig. 1). ML was the maximum distance from the uppermost margin of the head of the femur to the lowest margin of the medial condyle. VHD was the maximum vertical diameter of the femoral head. MTD was the transverse diameter at the middle of the shaft.

AB was measured on lateral views. Femoral curvature was accepted as an arch, and the radius of the imaginary circle to which this arch might belong was calculated both

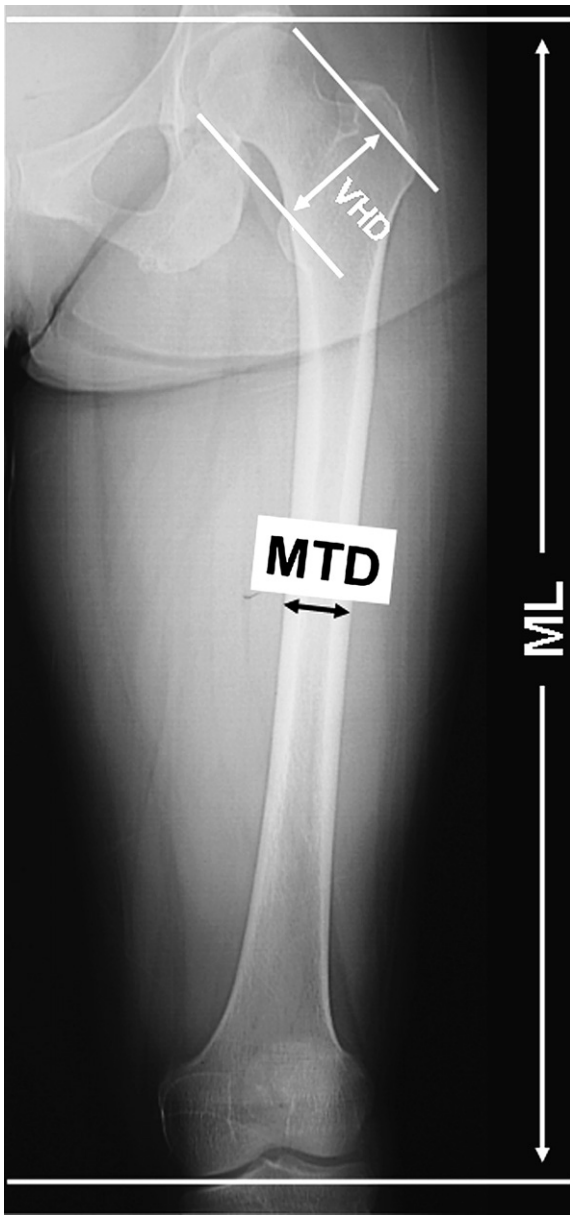

Fig. 1. Digital image in frontal projection. Maximum length (ML), vertical femoral head diameter (VHD) and femoral midshaft transverse diameter (MTD) measurements of the left femur.

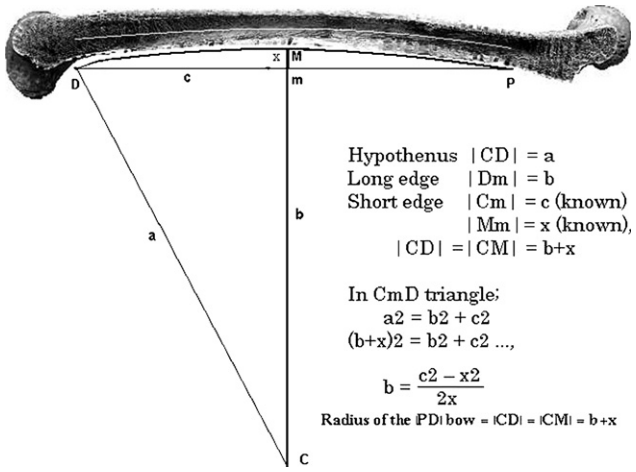

Fig. 2. The computation of the anterior bowing on the representative digital image in lateral projection (originally published under Ref. 11).

from the posterior cortex (Fig. 2). The three points that formed posterior cortical arch was defined as follows: Proximally, the lower edge of the lesser trochanter (P); distally, where the widening of the condyle begins (D); at the middle, the half distance between these two points (M). After the determination of these reference points, the line connecting proximal and distal points (PD) was traced. The distance between P and D and the shortest distance between PD line and the point M (Mm) was measured. The radius of the imaginary circle which this PMD arch belongs (namely the length of the hypotenuse of the triangle CmD) was calculated using the formula $a^2 = b^2 + c^2$ (for more refer to Fig. 2).

2.3. Statistical analysis

All results are expressed as the mean ± SD. Data were analyzed using Student's t test for independent samples, and Pearson's moment's correlation coefficients. In order to classify the subjects according to their sex, discriminant analysis was performed using binary logistic regression. ROC analysis was performed on significant discriminatory parameters. $p < 0.05$ was accepted as the level of significance.

3. Results

By design, there was no statistical difference regarding chronological ages of sex groups ($p = 0.665$) (Table 1).

Table 1
Chronological age and femoral measurements for males ($n = 50$) and females ($n = 54$)

Sex	Age	Maximum length (mm)	Vertical head diameter (mm)	Midshaft transverse diameter (mm)	Anterior bowing (mm)
Male	40.2 ± 15.3	448.2 ± 30.5	48.8 ± 2.9	26.5 ± 2.5	759.3 ± 269.6
Female	41.5 ± 14.3	419.0 ± 29.1	43.4 ± 3.6	25.6 ± 2.3	779.5 ± 267.3
P value	0.666	0.0001*	0.0001*	0.079	0.709

* $p < 0.05$.

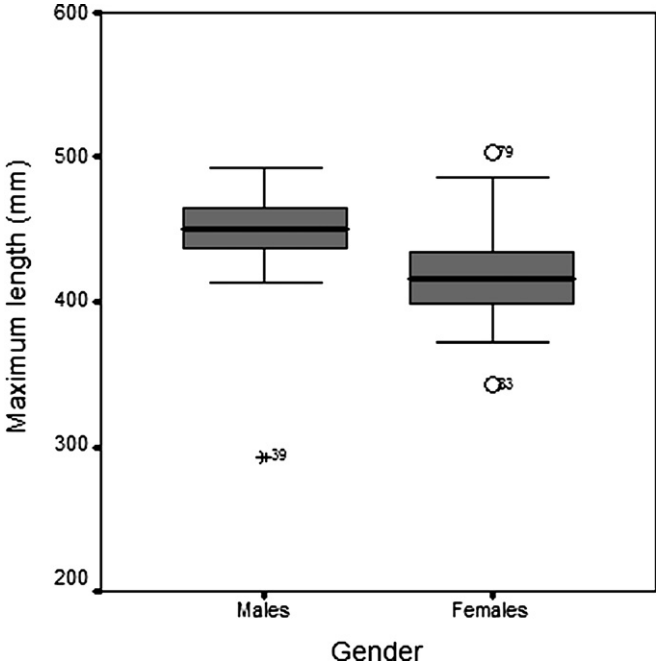

Fig. 3. Boxplot showing maximum femoral length for both sex types.

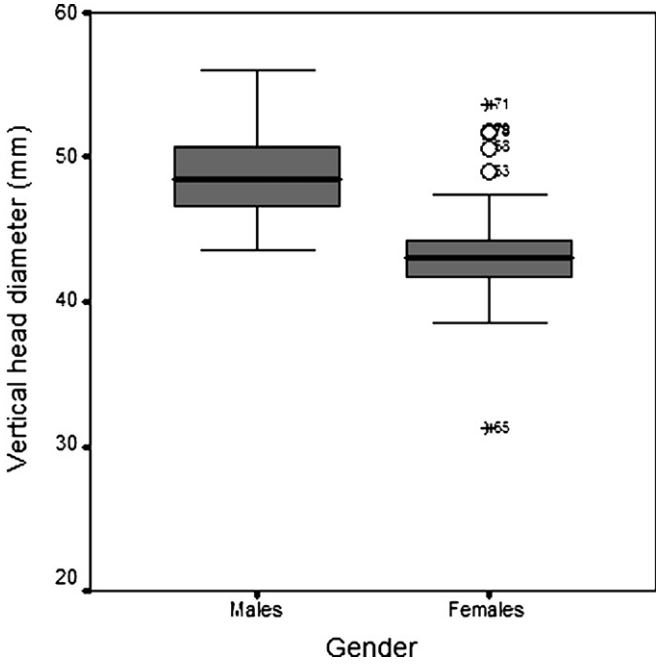

Fig. 4. Boxplot showing vertical head diameter for both sex types.

For males, mean ML was 448.2 mm, mean VHD was 48.8 mm, mean MTD was 26.5, and mean anterior bowing was 759.3 mm. For females these measurements were 419.0 mm, 43.4 mm, 25.6 mm, and 779.5 mm, respectively.

There was a significant difference between males and females regarding ML and VHD ($p < 0.0001$ for both). Males had higher values than females for both parameters (Figs. 3 and 4). There was no statistical difference between males and females regarding MTD and AB.

Significant parameters (ML and VHD) were used to classify subjects according to their sex. ML had the highest accuracy. With this parameter 83.3% of the subjects were correctly classified ($p < 0.0001$). With VHD, 76.9% of the subjects were correctly classified ($p < 0.0001$). When both parameters were combined, the overall accuracy was slightly improved to 84.6 ($p < 0.0001$) (Table 2).

According to ROC analyses, the sensitivity and the specificity of the VHD for sex determination were better than ML. For VHD, the cut-off value of 44.9 mm produced a sensitivity of 94% and a specificity of 83%. For ML, the cut-off value of 428.6 produced a sensitivity of 80% and a specificity of 67% (Fig. 5).

Table 2
Classification results for maximum femoral length and vertical head diameter

Observed membership	Predicted membership		
	Sex		Classification accuracy (%)
	Male	Female	
Sex			
Male	42	8	84.0
Female	8	46	85.2
Overall classification accuracy (%)			84.6

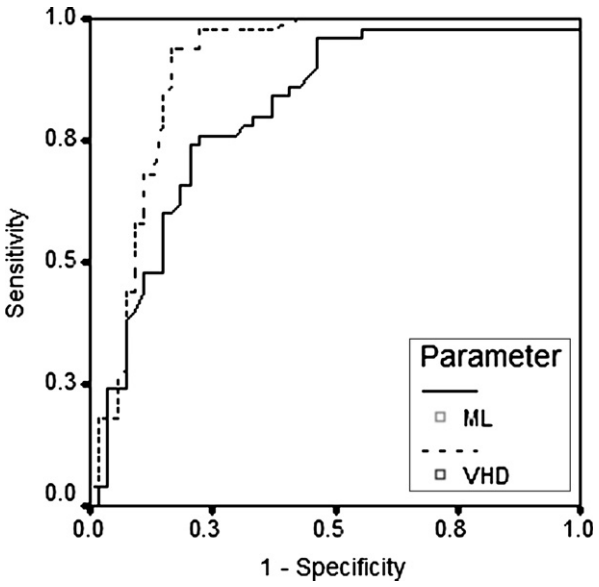

Fig. 5. ROC curves for maximum length (ML) and vertical head diameter (VHD) in sex determination.

4. Discussion

Femoral measurements have been performed on various ethnic groups.[1–10] Comparison of our findings with the already reported ones did not reveal a similarity of Anatolian Caucasians to any of the cited populations regarding all of the investigated parameters (Table 3). Anatolian males mostly resembled to white North Americans[6] regarding ML (448.2 mm vs. 450.0 mm), to Germans[1] and white South Africans[5] regarding VHD (48.8 mm vs. 49 and 48.5 mm), and to Portuguese[8] regarding MTD (26.5 mm vs. 26.4 mm). Anatolian females on the other hand, mostly resembled to white North Americans[6] regarding ML (419.0 mm vs. 423.0 mm), to white South Africans[5] and Portuguese[8] regarding VHD (43.4 mm vs. 43.0 and 39.9 mm), and to white North Americans[6] and white South Africans[5] regarding MTD (25.6 mm vs. 25.0 and 26.3 mm). Overall, Anatolian subjects mostly resembled to white North Americans regarding femoral anthropometrics.

Sex determination is one of the most important objectives of femoral measurements. In our study, only two parameters (ML and VHD) were significant for such classification. With ML, 83.3% of the subjects were correctly classified. With this parameter, Di Bennardo and Taylor[6] accurately predicted the sex of 80% of the white North Americans. In contrast, Mall et al.[1] correctly classified only 68% of the German subjects. Our mean ML values were similar to ML of white North American subjects for both sex types. Almost the same level accuracy was reached in both Anatolian Caucasians and white North Americans using this parameter in sex differentiation.

With VHD about 77% of the subjects were correctly classified. With this parameter, Mall et al.[1] could correctly classify 86.8% of the German subjects. However, the accuracy of VHD in determining the sex type of Anatolian Caucasians was substantially lower than above-mentioned subjects.

The anterior bowing was not dealt in the cited investigations and no comparison can be done for this parameter. However, there was no difference between either sex regarding this parameter.

The present study provides radiological measurements for four different parameters with relation to sexual dimorphism on an Anatolian Caucasian population. Although the sample size represented is relatively small, it is evident that different aspects of their femora are similar to different racial groups. In this context, none of the previously reported findings can be solely used for Anatolian Caucasians. This outcome may also be true for other populations that have not yet been studied. Therefore, their femoral measurements should also be performed and updated. This task may be challenging, as it requires the availability of cadavers and considerable time to prepare the samples. In this context, CT may be a feasible alternative due its widespread availability and to its high geometric accuracy.[11]

Table 3
Comparisons of mean values of femoral measurements for different ethnicities and sexes[a]

Measured parameter	Ethnicity						
	Anatolian Caucasians	Contemporary Chinese[4]	Early Chinese[3]	German[1]	Portuguese[8]	White North Americans[6]	White South Africans[5]
Females							
ML	419.0	394.1	401.0	434	398.0	423.0	437.6
VHD	43.4	38.4	41.1	44	39.9	NS	43.0
MTD	25.6	24.2	23.2	28	23.8	25.0	26.3
AB	779.5	NS	NS	NS	NS	NS	NS
Males							
ML	448.2	431.3	442.2	464	444.7	450.0	469.7
VHD	48.8	42.7	46.2	49	46.1	NS	48.5
MTD	26.5	26.7	25.7	31	26.4	28.0	29.1
AB	759.3	NS	NS	NS	NS	NS	NS

[a] All values are in mm, #: Citation number as in the references, AB: Anterior bowing, ML: Maximum length, MTD: Midshaft transverse diameter, NS: Not studied, VHD: Vertical head diameter.

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